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ACTIVE ELECTRO-OPTICAL FILTERING DEVICE AND PROCESS FOR OPERATING IT

The invention concerns an active electro-optical filtering device and a process for operating it in accordance with the generic terms of the independent claims. The filtering device is suitable in particular as a dazzle protection device for utilization in welding protection masks, -helmets or -goggles.

Filtering devices of this type are known, e.g., from the documents WO 97/15254, US-5,315,099 or EP-0 550 384. As active filter elements, they typically contain at least one liquid crystal cell (liquid-crystal-cell, LC-cell), which blocks the light transmission to a greater or lesser extent, as soon as a light sensor is impinged with a light intensity which exceeds a predefined threshold level. The utilization of such filtering devices is many and diverse; a typical example is the use as viewing window for welding protection masks, -helmets and -goggles.

The filtering devices described in the documents mentioned consist of active filter elements, for example made of 0-90° rotating nematic liquid crystal elements, which are located between two crossed polarizers. They are operated with an operating voltage which lies several times above the Fréedericksz threshold. Designated as Fréedericksz-threshold is the driving voltage of a liquid crystal cell at which a first optical activity of the cell can be observed. The choice of a higher operating voltage is justified in the above mentioned documents with a reduction of the scattered light

produced, a reduced dependence on temperature of the electro-optical effect and the creation of an optical transmission of less than 1 %.

The driving frequency of active filter elements like this for reasons of a low power demand lies between 0 and 32 Hz. Mentioned as the main reason for the limited availability of electric supply power is the operation of the filter elements using electricity from support/buffer batteries and solar cells. While continuous direct current operation today still damages liquid crystal cells through electrolysis and ion migration or else strongly impairs their optical performance capacity, by continuous improvement of the insulating layers, by the reduction of impurities and by the achievement of higher electric conductance values of the liquid crystal substances utilized significant progress has been achieved. The choice of an as low as possible driving frequency is strived for, because the drive frequency has a linear effect on the power demand of a liquid crystal cell. It would, however, be desirable to reduce the power demand even further.

Two values characteristic for such electro-optical filtering devices are of particular significance in this context: the transmission and the scattering. Requirements of these values are laid down in various product standards, e.g., EN 166, EN 167, EN 169 or EN 379. The European standard EN 169 prescribes within which range the transmission T may lie in case of various welding processes. In doing so, a protection level number

$$N = 1 - (7/3)\log T \tag{1}$$

is introduced. Permissible scattered light for active filter elements are defined in the European standard EN 379. In doing so, the reduced scattered light coefficient is defined as follows:

$$l^* = (1/\omega)(\varphi_{1R} - \varphi_{2R})/\varphi_{1L} \quad , \tag{2}$$

whereby

ω	is the spatial angle,
$(\varphi_{1R} - \varphi_{2R})$	is the scattered light flow of the test sample in the defined spatial angle (minus the scattered light proportion of the measuring installation) and
φ_{1L}	is the unscattered light flow of the test sample (zero diffraction order).

In the case of known electro-optical filtering devices, the optical quality is strongly impaired by scattered light. The light scatter on an LC-cell has various causes: amongst others, particles enclosed in the LC-cell, differing layer thicknesses, scratches, edges and/or spacers between the glass plates enclosing the liquid crystal.

It is the task of the invention to create an active electro-optical filtering device and to indicate a process for its operation, in the case of which an as low as possible operating voltage is required and nonetheless a good optical quality, in particular an as small as possible impairment of it due to light scattering, is achieved. The task is solved by the filtering device and by the process as defined in the independent claims.

For the reduction of the power demand of the liquid crystal cell, the electro-optical filtering device in accordance with the invention is in preference equipped with a special driving circuit. The driving circuit in accordance with the invention contains a switch, which in every half-period short-circuits the liquid crystal cell for a certain time period. Therefore neither a continuous trigger circuit nor a continually changing drive voltage is chosen. The drive in accordance with the invention differs from the state of the art by the insertion of an active flank and a drive process, which instead

of to a continuous frequency, corresponds rather more to a pulse width modulation. The framework frequency of the driving pulses lies in the range of 0.01 to 1 Hz. The energy requirement with this process is halved in comparison with the state of the art, which represents an enormous progress.

The invention presented here utilizes an operating voltage which is unequivocally defined. On the one hand, it is several times above the Fréedericksz-threshold, in order to achieve the optical density prescribed in the product standard EN 169. In addition, the operating voltage is defined in such a manner, that it lies at the voltage, at which the light scattered by the LCD display is minimal.

The definition of the operating voltage in accordance with the invention consists in the finding that a minimum of scattered light is achieved, when in the scattered light equation (2) the numerator (essentially φ_{1R}) is smaller or else the same value as the denominator (φ_{1L}). In other words this signifies: if the scattered light proportion φ_{1R} in the operating point of the liquid crystal display is adjusted to be smaller than or equal to the residual transmission $T = 10^{(3/7)(1-N)}$, then the operating voltage has been selected as optimized with respect to scattered light. Operating frequencies defined in such a manner according to experience lie in the range of 10 to 50 Volt. The adjusting of the residual transmission can, for example, be solved with a small offset of the polarizer orientation or with an adaptation of the polarization efficiency. The scattered light influence of the measuring installation (φ_{2R}) has been neglected in the above discussion.

In the following, the invention is described in detail on the basis of Figures. These illustrate:

Fig. 1 a filtering device in accordance with the invention executed as a dazzle-protection device,

Fig. 2 an equivalent circuit diagram of a control circuit in accordance with the invention,

Fig. 3 the operating voltage in function of time for a preferred embodiment of the operating process and

Fig. 4 the reduced radiant luminance in function of the operating voltage.

In **Figure 1,** a filtering device in accordance with the invention designed as a dazzle-protection device is illustrated. It contains at least one active optical filter element 1 with a liquid crystal. The liquid crystal is implemented in accordance with one of the following technologies: TN-technology, STN-technology, dichroic technology, ferro-electric technology or π-Mode-LCD-technology. Apart from this, the filtering device contains electronic means 2 for driving the active filter element 1. At least one light sensor 4 acts in conjunction with the electronic means 2. Brought to the electronic means 2 are, for example, output signals of the light sensors 4 for the purpose of controlling, resp., closed-circuit controlling the operating voltage of the filter element. For the electronic means 2, the optical filter element 1 and possibly the light sensors 4, electric power supply means 5 are foreseen. These can be implemented, e.g., as solar cells.

It is advantageous to equip the electronic means 2 with a driving circuit, as is schematically illustrated in **Figure 2.** With this, the power demand of the liquid crystal cell 1 can be significantly reduced. The liquid crystal on the equivalent circuit diagram of Fig. 2 is represented by a resistor R_{LC} and a capacitor C_{LC}. Other resistors in the circuit are combined in the resistors R_{S1} and R_{S2}. An alternating current source 21

supplies an alternating current $U_{\approx}$ with a framework frequency f of typically 0.01 to 1 Hz. The drive circuit in accordance with the invention contains a switch S_1, which short-circuits the liquid crystal cell for a certain time period t_s. This effects the complete discharge of the capacitor C_{LC}. The energy required for the anti-polar charging of the capacitor C_{LC} with this drive circuit is therefore halved in comparison with the state of the art.

Figure 3 shows the operating voltage U(t) supplied by the drive circuit in accordance with Fig. 2 in function of the time t. In a time period T with a typical duration of 1 to 100 sec, initially during a first time interval t_+ a, for example, positive voltage $+|U_{LC}|$ is applied to the liquid crystal cell 1. Thereafter, e.g., by closing the switch S_1 (refer to Fig. 2), during a second time interval t_{S1} the liquid crystal cell 1 is short-circuited. During a third time interval t_- thereupon a, for example, negative voltage $-|U_{LC}|$ is applied to the liquid crystal cell 1, whereupon during a fourth time interval t_{S2} once again a short-circuit takes place. In this manner, therefore active flanks 31, 32 are inserted into the course of the operating voltage U(t). This drive process in accordance with the invention corresponds most likely to a pulse width modulation. The framework frequency f = 1/T of the driving pulses lies in the range of 0.01 to 1 Hz. It has to be observed, that the time intervals in Fig. 3 for reasons of clarity are not depicted to scale: While the first time interval t_+ and the third time interval t_- have typical lengths of 0.5 to 50 sec, typically the lengths of the second time interval t_{S1} and of the fourth time interval t_{S2} lie in the range of microseconds to milliseconds. The short-circuit times t_{S1}, t_{S2} are therefore shorter than the drive times t_+, t_- by factors in an order of magnitude of 10^3 to 10^7.

Figure 4 illustrates a typical dependence of the reduced radiant luminance coefficient $l^*(U)$ (refer to equation (2)) in function of the operating voltage U. The analysis of the scatter phenomenons on a liquid crystal cell 1 is important for the comprehension of the invention. Causes of the light scattering are, for example, particles en-

closed in the liquid crystal cell 1, differing layer thicknesses, scratches, edges and/or spacers between the two glass plates enclosing the liquid crystal. In the case of scattered light, one can differentiate between a static proportion l^*_s and a dynamic proportion l^*_d. The static scattered light proportion l^*_s can by means of suitable technical measures be reduced to such an extent, that the user of an active dazzle-protection filter does not have to be subject to an impairment of the image quality (scattered light class 1, in accordance with European standard EN 379). Completely different is the situation in the case of the dynamic, voltage-dependent scattered light proportion l^*_d. Around the scattered light centres mentioned above, when an operating voltage U is applied, a local orientation disruption is produced. The foreign substance – or the edge – causing the scattered light centre disrupts the homogeneous, chiral orientation of the liquid crystal molecules. These local orientation disruptions are to a great extent responsible for the voltage-dependent scattered light proportion l^*_d. With a higher operating voltage U, the liquid crystal molecules are aligned more and more parallel to the field strength vector and therefore the local orientation disruption is made to disappear.

The reduced radiant luminance coefficient l^* illustrated in Fig. 4, in accordance with the equation (2) is essentially the ratio of the scattered light flow φ_{1R} and the unscattered light flow φ_{1L}. In the case of the curve $l^*(U)$, three ranges can be differentiated between.

I. For low operating voltages U, φ_{1R} is $<$ φ_{1L}, therefore l^* is < 1. In this first range I, φ_{1L} is reduced more strongly with increasing U than φ_{1R}, for which reason $l^*(U)$ increases monotonously.

II. For medium operating voltages U, φ_{1R} is $\approx$ φ_{1L}, therefore l^* is ≈ 1. In this second range II, $l^*(U)$ is approximately constant.

III. For high operating voltage U, once again $\varphi_{1R} < \varphi_{1L}$ is applicable, therefore l^* < 1. In this third range III, φ_{1L} is reduced only a little with increasing U or is approximately constant, while on the contrary φ_{1R} for the reasons mentioned above still reduces, for which reason $l^*(U)$ is monotonously reduced.

In accordance with the invention, the operating voltage $U = U_{LC}$ is selected in such a manner, that the following conditions are fulfilled:

a) The required transmission is achieved;

b) The reduced radiant luminance coefficient l^* is minimal.

The operating voltage U_{LC} is determined from this as follows. The condition a) defines a band on the U-axis, in which the operating voltage U_{LC} has to be, in order to achieve the required transmission. In this band thereupon, in accordance with condition b) the operating voltage U_{LC} is unequivocally determined, so that l^* becomes minimal. Normally the operating point U_{LC} is situated in the third range III of the curve $l^*(U)$.

If so required, the transmission can be adjusted by a slight rotation relative to one another of the polarizers or by an adaptation of the polarizer efficiency.